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AEC RESEARCH AND DEVELOPMENT REPORT

SPACE RECORDER OPERATING MANUAL PRD-1

AUTHOR:

L. M. Carter, Jr.

This document has been approved for release to the public by:
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CARBIDE AND CARBON CHEMICALS COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION
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Approved for Issue: J. A. Parsons
Date of Issue: April 14, 1955
Report No. K-1212
Subject Category: SPECIAL

PPD-1

SPACE RECORDER OPERATING MANUAL

L. M. Carter, Jr.

CARBIDE AND CARBON CHEMICALS COMPANY
K-25 Plant
Oak Ridge, Tennessee

CLASSIFICATION CHANGED TO Unclassified
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FOREWORD

The space recorder has become a much more common instrument in the operation of gaseous diffusion plants. Initially, this instrument was only used in conjunction with purge cascade operation, while its present use has been expanded to include numerous cold trap facilities. The more extensive application of the instrument has not been accompanied by simplification of its use. Further, under the varying conditions of assay, flow, and temperature encountered in cold trap service, the performance of the instrument has become more complicated.

This operating manual for the space recorder was written to facilitate its operation in new cold trap installations by those personnel unfamiliar with its performance. Further, it is needed to have an up-to-date manual to increase the efficiency of its operation and to instill confidence in the operators with the accuracy of the instrument.

Recent modifications of the space recorder and new components of the instrument are discussed from an operational standpoint. A general procedure which can be used at all cold trap space recorder installations is given for the performance of certain basic space recorder operations.

SPACE RECORDER OPERATING MANUAL

INTRODUCTION

The analysis of gas in the purge cascade is complicated by the variation of the stream from essentially pure uranium hexafluoride near the bottom of the cascade to only small traces near the top of the cascade. The line recorder is normally employed for continuously analyzing the gas in the cascade. A pirani flow meter measures the flow of gas to this instrument; the uranium hexafluoride is removed chemically before it reaches the spectrometer tube--after which the residual gases are analyzed. The amount of uranium hexafluoride is then the difference between the amount of gas flowing through the flow meter and the amount of gas analyzed by the spectrometer tube. It is very difficult to obtain either reading with greater than 99.0 per cent accuracy; therefore, the possible cumulative error in measuring uranium hexafluoride is 2.0 per cent. Thus, the line recorder is of little value for determining the exact proportion of uranium hexafluoride in gas mixtures with less than 2 per cent uranium hexafluoride.

The purge cascade and buildings used as side purges have gas mixtures ranging from close to 100 per cent uranium hexafluoride to as little as 1×10^{-6} per cent uranium hexafluoride. Concentrations of 2 to 100 per cent uranium hexafluoride are determined by the use of the line recorder and supplementary instruments. The need for a device to measure concentrations of less than 2 per cent uranium hexafluoride is thus indicated; therefore, the space recorder was devised.

The principal component of the space recorder is an ionization chamber (referred to as the signal can), which measures the specific radioactivity of the gas present. Since uranium hexafluoride is an emitter of alpha particles, it provides a method for measuring the uranium hexafluoride content of gas samples. With the signal can, it is possible to detect the presence of mole-fractions of uranium hexafluoride of the order of 10^{-6}. Its upper range is limited only by the radioactive contamination produced in the signal can by high concentrations of uranium hexafluoride. This device thus conveniently supplements the line recorder in the purge and cold trap facilities.

THEORY

A. Ionization by Alpha Emission

Since uranium hexafluoride is radioactive, there is an emission of alpha particles (nuclei of helium atoms). Each of the four uranium (U-234, U-235, U-236, U-238) isotopes present in the cascade emits alpha particles at a different rate; therefore, any mixture of the four isotopes emits alpha particles at a rate dependent upon the relative proportions of the constituents. The range of travel of alpha particles in a gas is very definite and is directly proportional to the absolute pressure. The particles expend their energy by ionizing molecules. This occurs when the positive alpha particle passes near enough to a neutral molecule to pull out an electron, thus leaving the remainder of the molecule positively charged. The grid in the signal can has a positive potential with respect to the walls and collector wire, and, since like charges repel, positive ions formed within the grid are accelerated to the collector wire. Similarly, ions formed outside the grid are accelerated to the walls. Each ion that is collected by the collector wire takes on an electron, causing electron flow through a preamplifier input resistor. This current is amplified and measured and constitutes a determination of the uranium hexafluoride concentration. Radioactive materials emit particles at different rates. A measure of the rate of emission is denoted as a decay constant.

B. Design of Signal Can for Alpha Emission

It was concluded from experiments with the above considerations that a cylindrical signal can with a 24-inch inside length and a 12-inch inside diameter, operating at a pressure of 10 psia, would have the desired sensitivity. The sensitivity tends to increase as the pressure is raised above 10 psia, but the rate of recombination of the ions formed in the signal can also increases. This fact, in conjunction with factors involving the design of a pump, makes 10 psia the optimum operating pressure.

Due to the corrosive nature of uranium hexafluoride, the grid wires and supporting wires are made of nickel, while the interior of the signal can is nickel-plated. The 25-mil collector wire, as shown in figure 3, is mounted axially in the signal can. The plastic M.F.P. vacuum-tight seal reduces ion leakage to an absolute minimum. The grid, which is essentially a wire cage 19 inches long and 8 inches in diameter, is mounted concentrically around the collector wire. The individual wires, 3 mils in diameter and 1 inch apart, are maintained at a potential of either 300 or 750 volts.

With the collector operating at ground potential, positively charged ions--created within the grid cage by the collision of uranium hexafluoride alpha particles with molecules--are drawn toward the more negative collector. The ions outside the grid are accelerated away from the collector wire. Hence, the only ionization contributing to the signal other than residual ionization occurs inside the grid cage.

C. Residual Ionization

1. The residual ionization, called "Background," is a result of:

   a. Ionization caused by beta particles and gamma rays caused by disintegration products deposited on the walls of the signal can.

   b. Ionization caused by non-volatile uranium deposits which result from the chemical reaction of uranium hexafluoride with the grid assembly and the inside surface of the signal can. These non-volatile compounds emit alpha particles which are the most serious source of the background signal.

2. Effect of Pressure on Background: At the normal operating pressure of 10 psia, residual ionization due to the emission of alpha particles from the wall is at a minimum. Hence, at this pressure practically all of the background is the result of the non-volatile uranium products deposited on the grid. As the pressure is decreased the range of the alpha particles from the wall and grid structure increases. This increases the signal until a maximum is reached at a pressure of 2.6 psia, below which the background signal decreases rapidly. This is illustrated by figure 1.

3. Effect of Uranium Hexafluoride on Background Rise: The background at operating conditions will increase at a rate dependent upon the concentrations of uranium hexafluoride and the exposure time. Thus, if high concentrations are introduced into the signal can over extended periods, a rapid rise in background will occur. A plot of background versus hour-per cent (average concentration multiplied by the exposure time) yields a curve indicating the background signal trend (see figure 2).

4. Effect of Process Contaminants on Background: There is a comparison in figure 2 between two identical signal cans which were operated under different conditions. In the one case (represented by curve B) a signal can was operated under dynamic or flow conditions. Curve C presents the background versus hour-per cent exposure for an identical signal can operated under static conditions. The latter curve has a steady rise and depicts the ideal relationship between background and hour-per cent exposure. Curve B, on the other hand, exhibits erratic background rise at certain values of hour-per cent, although the average slope of the curve beyond 3 hour-per cent is approximately the same as that for curve C.

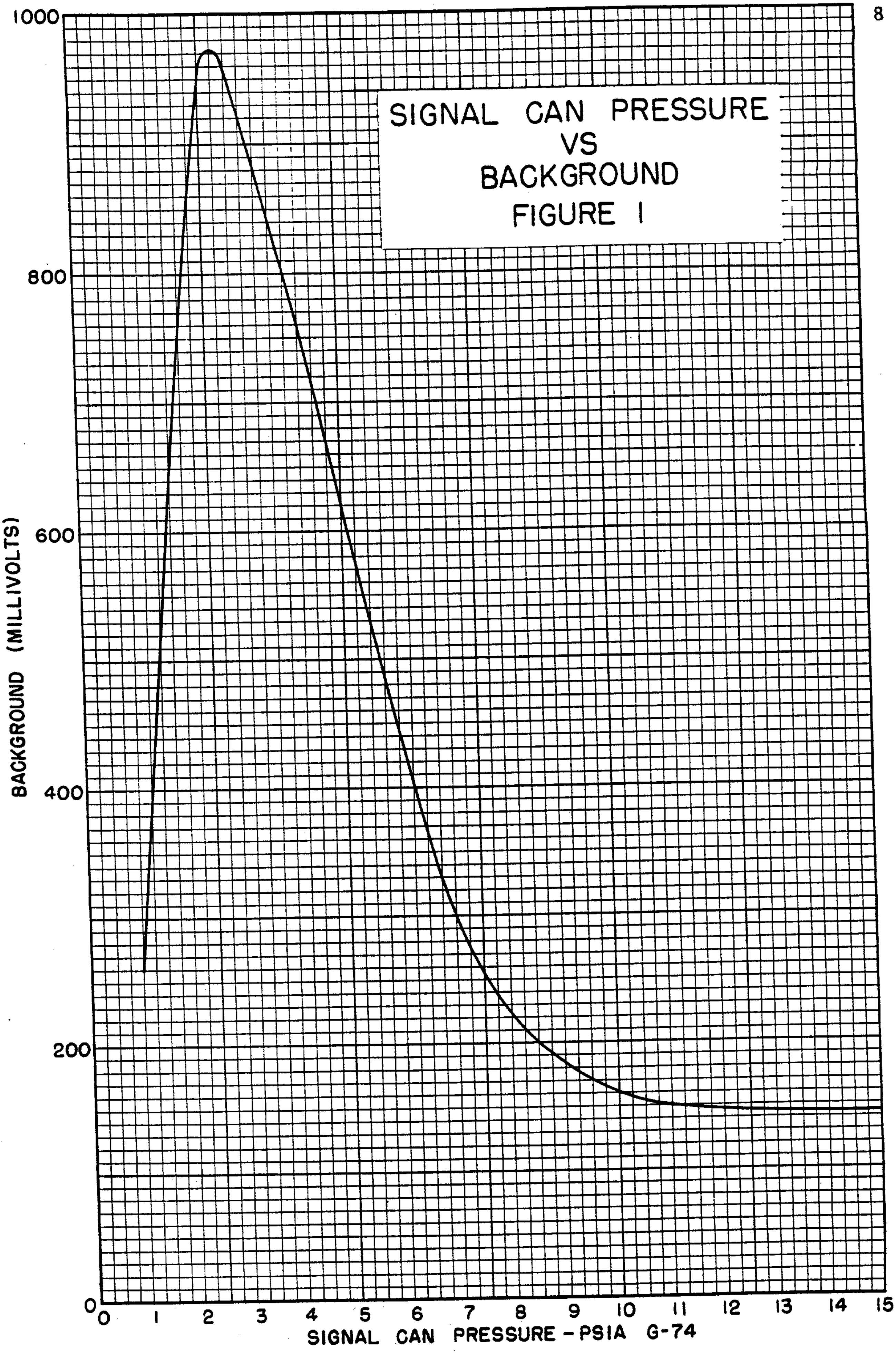
   Curves A and D also represent signal cans operated under static conditions. Curve A, unlike curves B, C, and D, represents a signal can which did not receive an additional baking-out period after conditioning (see "Methods of Conditioning the Signal Can").

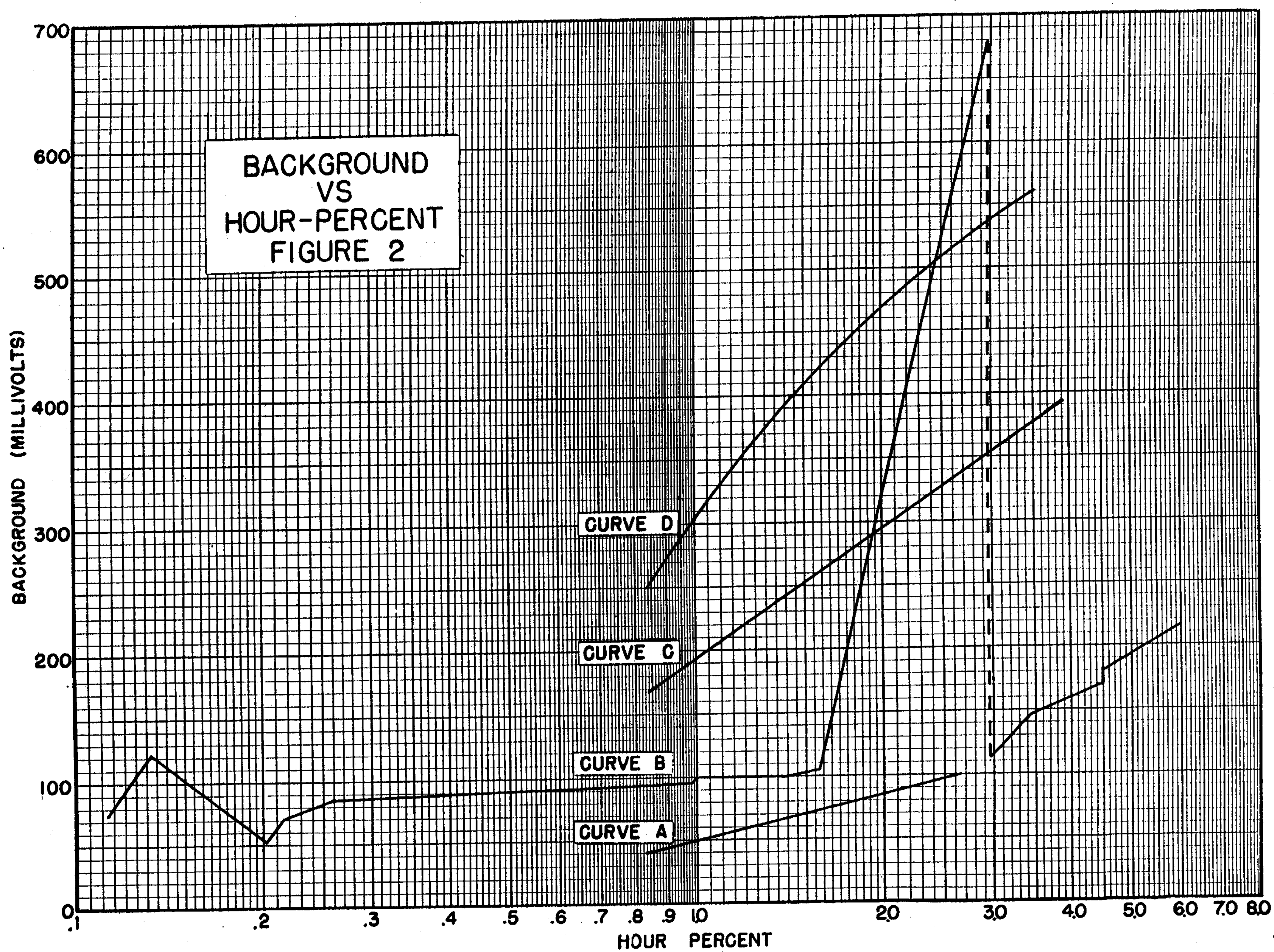
A satisfactory explanation for the sudden increase in background shown by curve B has never been determined. However, it appears that there are contaminants in the process gas which indirectly contribute to this effect. If these contaminants were not easily vaporized, they would remain in the signal can for a considerably longer time than that required for a change of sample at the normal flow rate. It is thus possible that the contaminants would trap uranium hexafluoride molecules and prevent their being swept out of the signal can. This effect, although of a continuous nature, is more pronounced immediately after admitting gas high in uranium hexafluoride concentration, and would cause a temporary rise in background until removed by continued purging.

5. Methods of Conditioning the Signal Can: The method of conditioning the signal cans may have a considerable effect upon the background rise. The conditioning treatment, which consists of the introduction of gaseous fluorine, removes water vapor and forms a corrosion-resistant film on the inside surface of the signal can. Prior to exposure to the fluorine, the signal can is evacuated to a pressure of less than 10^{-4} mm of Hg and baked at 70°C. The fluorine mixture (25 per cent fluorine and 75 per cent nitrogen) is then admitted to the signal can at atmospheric pressure while maintaining the temperature at 70°C. Approximately 40 hours are required for complete conditioning.

   An additional bake-out period after conditioning to remove additional moisture and contaminants proved to be ill-advised since it was found that the background of a signal can conditioned by this procedure has a tendency to rise more rapidly with the introduction of high concentrations of uranium hexafluoride than signal cans which were not subjected to the supplementary bake-out period.

   Background versus hour-per cent curves are shown in figure 2 for each conditioning procedure. A means of reducing the signal can background by chlorine trifluoride treatment is discussed under "Operation of the Space Recorder."


SIGNAL CAN PRESSURE
VS
BACKGROUND
FIGURE I
1000
800
600
400
200
0
BACKGROUND (MILLIVOLTS)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SIGNAL CAN PRESSURE - PSIA G-74



BACKGROUND
VS
HOUR-PERCENT
FIGURE 2
CURVE D
CURVE C
CURVE B
CURVE A
BACKGROUND (MILLIVOLTS)
HOUR PERCENT
0
100
200
300
400
500
600
700
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

CONSTRUCTION OF THE SPACE RECORDER

Signal Can

The signal can consists of a valved, vacuum-tight cylinder through which sample gas flows. The interior of the signal can is nickel-plated. The electrical elements consist of a grid network of fine nickel wire and a collector wire to receive positive ions. The signal cans are of two types, JS-356 and JS-866. The JS-866 differs from the former model only in that it is provided with a protective buffer zone of nitrogen. Nitrogen is introduced through a small pipe attached to the collector sleeve of the signal can. The buffer zone of nitrogen serves to protect the collector insulator and permits the use of the space recorder with gases which would otherwise deposit out and cause leakage across the collector insulator.

Specially adapted flanges and associated gaskets are utilized to connect the signal can into the plant stream. The design and construction of the signal can are discussed more thoroughly in "Theory of Operation."

Preamplifier and Amplifier

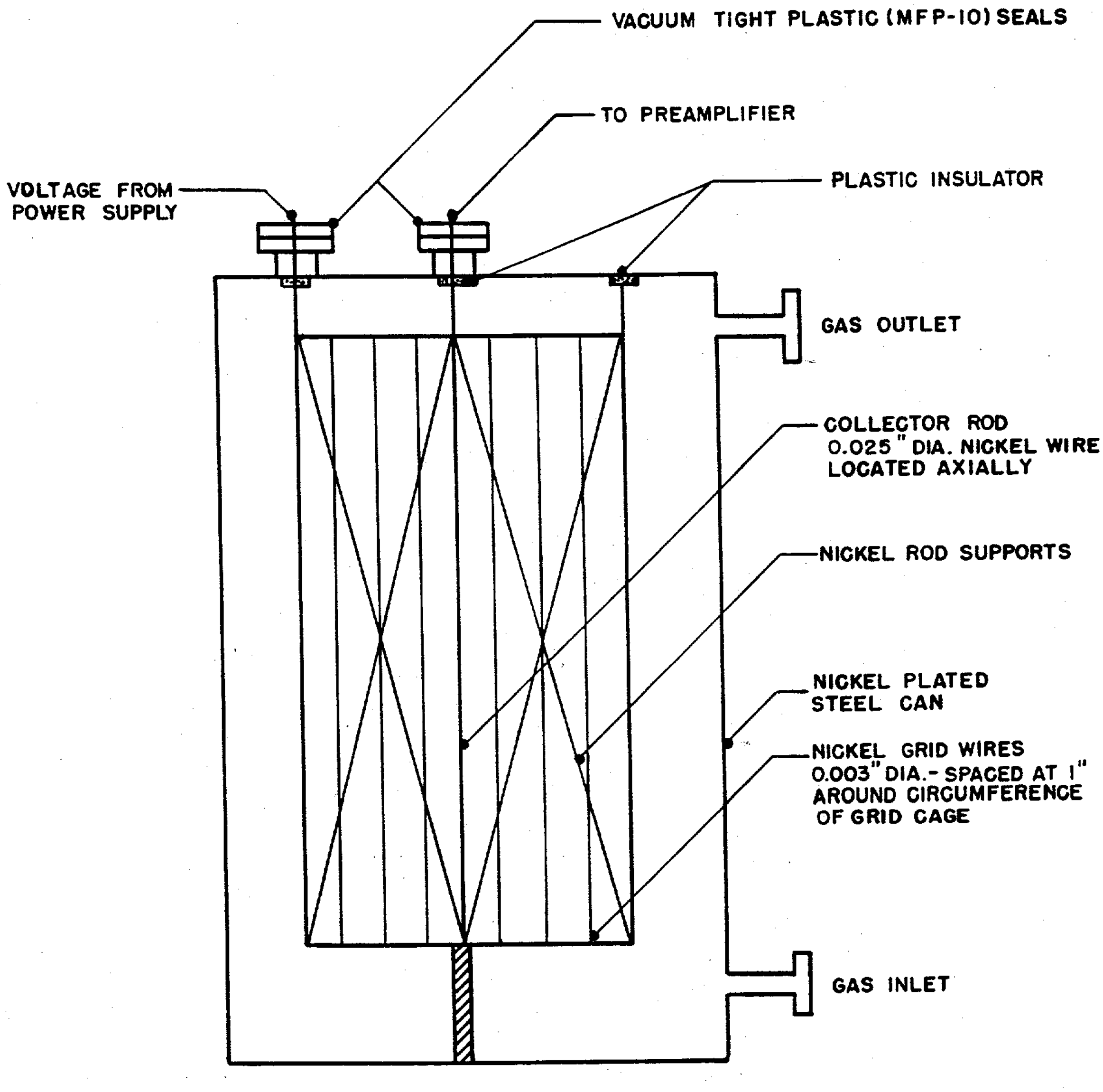
The signal can was designed and constructed to measure the concentration of gas ions within the can. The ionization current is subsequently measured by a direct current amplifier as it flows through a large resistance. The amplifier incorporates a 100 per cent negative or degenerative feedback circuit which greatly increases stability. In the feedback circuit, the change in output voltage (which is indicated on a millivolt meter) is the same as the voltage change across the high input resistance. This latter voltage change is due to the variation in electron flow to the signal can collector and is proportional to the rate of ion collection.

There are presently three distinct electronic arrangements of the space recorder and its components. Further, an additional combination may exist later since an entirely new signal can is now under consideration.

The preamplifier contains an electric (zero) switch that may be operated manually but which normally is operated automatically by a timer. This timer is set so that for three minutes in each thirty, the ion current does not flow through the grid resistor of the preamplifier. This not only provides a continuous check on amplifier zero, but also provides a zero or reference curve on the recorder chart to which the signal curve may be compared. Actuation of the manual switch will not disturb the cycle of automatic zeroing. A shorting type switch is used for changing the contact and connects the collector wire from one end of the grid resistor to the other. The purpose for employing a shorting type switch is to prevent the collector from acquiring the potential of the surrounding grid during switching; thus, a large transient pulse is imparted to the amplifier when it is again connected to the high end of the grid resistor.

SIGNAL CAN CONSTRUCTION

FIGURE 3



CAN DIAMETER= 12"
GRID CAGE DIAMETER= 8"
CAN LENGTH= 24"
GRID CAGE LENGTH= 19"

The range of the General Electric preamplifier may be extended by reducing the sensitivity by a factor of 100. This is accomplished by connecting a resistor having a resistance of 2×10^8 ohms in parallel with the normal grid resistor of 2×10^{10} ohms.

The Westinghouse preamplifier consists of the first two stages of a 100 per cent feedback direct current amplifying system. The first stage is an electrometer tube and the second stage is a 954 amplifier tube. The input resistor to the electrometer tube may be switched from 2×10^{11} ohms to 2×10^9 ohms by means of a Victoreen VX-10 thermal switch operated by a manual switch on the power supply and switching panel (JS-356 C or L). When the input signals are large, the latter resistor may be chosen and the preamplifier sensitivity subsequently reduced to one per cent of the sensitivity attained with the high resistor.

The over-all drift of the amplifying system is checked periodically by a VX-10 thermal switch across the electrometer input. A timer switch in the power supply and switching panel actuates this thermal switch. The preamplifier assembly is fabricated of corrosion-resistant steel.

The direct current amplifier is used with the preamplifier for amplification of the ion current signal. Either of two types of amplifiers may be used. A JS-307G amplifier (which is identical to those employed in the line recorders) has eight recorder sensitivity switches, of which one is used to adjust the recorder range, while the JS-307U type has none. When a JS-307U amplifier is used, the single recorder sensitivity switch is located on the power supply and switching panel (JS-356L).

Balancing controls and an output meter with sensitivity factors from X1 to X1000 are provided. Sensitivity factors are obtained by means of meter multiplier resistors.

Micromax

This instrument, which is mounted in the panel rack, is a Leeds and Northrup self-balancing potentiometer which inks a continuous record of the signal.

The output millivoltmeter of the direct current amplifier is of use only in zeroing the amplifier and in checking the micromax when faulty operation of the latter is suspected. The balancing range of the slide wire in the micromax is 200 millivolts full-scale or 0-180 millivolts for positive signals. The remaining 10% of the slide wire is the negative portion of the scale. Thus, fluctuations in the amplifier, which might cause the zero reading to drift below zero on the scale, may be taken into account.

The micromax may also be equipped with a transmitting slide wire for the parallel operation of a remotely located micromax. In such an installation the micromax located in the space recorder station is termed the "Transmitter Recorder," and the remotely situated micromax is termed the "Slave Recorder." In those stations which have two space recorder installations, a "Transmitter Selector Panel" is mounted in the panel rack which permits the station operators to switch to either micromax for transmission of its reading to the slave recorder.

The Cooling System

In order that predetermined conditions will exist, the temperature inside the manifold is regulated by a temperature controlling device in conjunction with a heat exchanging unit. The air is circulated by a centrifugal blower through a water-cooled chamber.

Control Valve, Precisor, and Fulscope Controller

A P.B.M. (0-15 psia) is connected in the gas stream between the signal can and the main control valve. The output of the transmitter becomes the input to a Fulscope controller. This controller is attached to a precisor which controls the air pressure to the control valve.

Voltage Regulation

The potential applied to the grid structure of the signal can may be set at either 300 or 750 volts positive with respect to ground. A rectifier is employed and the voltage is held constant by the use of VR-type voltage regulator tubes. Fluctuations are eliminated by a filter consisting of a resistance of 5 megohms and a capacity of 2 microfarads.

Booster Pump

In the K-312 space recorder installation, two type B-4 pumps connected in series raise the pressure from the plant value to 10 psia - the normal operating pressure of the signal can. Control valves 2 and 3 determine the pressure behind the bellows of the two pumps. For maximum bellows life, each should be set at a value which is the arithmetic mean of the respective inlet and outlet pressures.

In the remaining space recorder installations throughout the cascade, the pumping facilities of existing Beach-Russ pumps are utilized, eliminating the need for additional B-4 pumps.

Alarm Panel

The alarm panel is used in conjunction with the recorder. When the recorder signal deviates from pre-set limits, a buzzer and pilot lights on both the recorder and the alarm panel are actuated.

Power Supply and Switching Panel

The power supply and switching panel (JS-356C) supplies a direct current voltage for the signal can grid, and provides a voltage source and control for the operation of the VX-10 thermal switches of the preamplifier. The signal can grid voltage is obtained from a full wave, condenser input filtered power supply using a 5R4GY rectifier tube. Five voltage regulating tubes (VR-150) across the rectifier output are used to obtain regulated grid voltages of 300 and 750 volts dc.

The direct current amplifying system is automatically zero checked for a three-minute period out of every one-half hour of operation. It may be zeroed manually at any time by shorting out the timer switch contacts. Another switch, for controlling the direct current amplifying system sensitivity, permits shunting of the 2×10^{11} ohm input resistor by a 2×10^{9} ohm resistor for operation on low. (Note: When the General Electric preamplifier is used, these values would be 2×10^{10} and 2×10^{8}, respectively.)

The JS-356L power supply and switching panel differs from the JS-356C unit in that the former contains a recorder sensitivity switch. This switch is required only when the direct current amplifier without sensitivity switches (JS-307U) is used.

SIGNAL CAN CALIBRATION

Calculation of Mole Per Cent

For the sake of simplicity and within acceptable limits of accuracy, it is assumed that the signal can is filled with a binary mixture of gaseous nitrogen and uranium hexafluoride of unknown proportions. A pressure of 10 psia and a temperature of 140°F. are assumed within the signal can. Actually, the pressure could be maintained at values other than 10 psia; for such a case, corresponding corrections must be made in calculating the mole per cent. In the derivation of the basic equation for mole per cent calculation, it is assumed that the uranium hexafluoride used is in the non-enriched state. However, when enriched material is measured, correction for this factor may also be made.

The concentration of uranium hexafluoride in the signal can may now be calculated by applying known physical laws. Avagadro's Number, 6.023×10^{23}, represents the number of molecules of a gas or gaseous mixture in 22,400 cc at standard conditions (defined as 32°F. and 14.7 psia). It is further assumed that the gases under consideration obey the perfect gas law. The grid structure, eight inches in diameter and nineteen inches long, has a volume of 15,650 cc.

Therefore, the number of molecules (N) of gas in 15,650 cc at 140°F. and 10 psia is given by the equation:

$$N = (6.023 \times 10^{23}) \times \frac{15,650}{22,400} \times \frac{10.0}{14.7} \times \frac{492}{600} \qquad (1)$$

or

$$N_1 = (6.023 \times 10^{23}) \times \frac{15,650}{22,400} \times \frac{10.0}{14.7} \times \frac{492}{600} \times \frac{(\text{mole \% UF6})}{100} \qquad (2)$$

where N_1 = number of uranium hexafluoride molecules.

The rate at which uranium-235 in normal uranium hexafluoride gives off alpha particles is equal to the product of the decay constant (2.47×10^{-17}/sec.) and the number of uranium hexafluoride molecules. Each particle ionizes an average of 132,000 gas molecules. Each ion formed has a charge equal to 1.6×10^{-19} coulomb. The isotopic fraction of uranium-235 in normal uranium hexafluoride is 0.007115.

Therefore:

$$I = (6.023 \times 10^{23}) \left(\frac{15,650}{22,400}\right) \left(\frac{10.0}{14.7}\right) \left(\frac{492}{600}\right) (1.6 \times 10^{-19}) \times (0.007115)(2.47 \times 10^{-17})(132,000) \left(\frac{\text{mole \% UF6}}{100}\right)$$

or

$$I = 8.7125 \times 10^{-12} \text{ (mole per cent uranium hexafluoride)}$$

where

I = current in amperes (3)

The above equation was derived considering uranium-235 only. To correct the equation so that it will apply for normal uranium hexafluoride which includes other isotopes of uranium, it must be multiplied by the factor 54.44. This factor was obtained from the following data:

	I Isotopic Fractions in Normal UF6	II Decay Constant	III Number of Ions Formed in Gaseous Nitrogen by One Alpha Particle
U-238	0.992834	4.90×10^{-18}	125,000
U-235	0.007115	2.47×10^{-17}	132,000
U-234	0.000051	8.72×10^{-14}	142,000

By multiplying columns I, II, and III together for each isotope of uranium, the proportionate number of ions formed by each isotope of uranium is determined. Therefore, the total number of ions formed relative to those formed by the uranium-235 equals 12.6281/0.23198 = 54.44.

Since this factor is variable due to the increased activity of uranium hexafluoride as it is enriched in the cascade, the factor will be assigned the letter K' for the remainder of this section, and will be combined into the factor K.

Equation (3) thus becomes:

$$I = 8.7125 \times 10^{-12} \text{ (K') (mole per cent)} \quad (4)$$

or $$\text{mole per cent} = 1.148 \times 10^{11} \frac{I}{K'}$$

or $$\text{mole per cent} = 1.148 \times 10^{11} \frac{E}{RK'} \quad (5)$$

where $E = IR$; E = Signal in volts; and R = input resistance in ohms

or $$\text{mole per cent} = 1.148 \times 10^{8} \frac{e}{RK'} \quad (6)$$

where e = signal in millivolts

When the sensitivity multiplication factor is one, each unit subdivision of the scale is equal to two millivolts.

Therefore:

$$\text{mole per cent} = \frac{1.148 \times 10^{8} \text{ micromax reading* } \times 2 \times \text{ sensitivity}}{R \times K'} \quad (7)$$

* Important - The micromax reading in equations (7) and (8) actually refers to the micromax reading minus the background reading at the same sensitivity.

Since there are two values of input resistance for each of the two types of preamplifiers in use, there are four values of R which may enter into the equation; the applicable values will be determined for each space recorder installation. The values are: 2×10^8, 2×10^9, 2×10^{10}, and 2×10^{11} ohms. Thus, for the above example of normal uranium hexafluoride, equation (7) becomes:

$$\text{mole per cent} = 4.217 \times 10^6 \, \frac{\text{micromax reading x sensitivity}}{R} \qquad (8)$$

The constant 4.217×10^6 for the above conditions is designated the K factor and will vary with different locations throughout the cascade.

The general equation will then be:

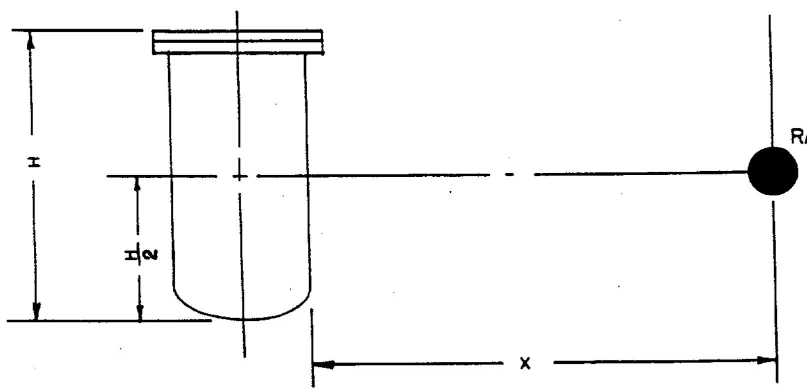
$$\text{mole per cent } UF_6 = K \, \frac{\text{micromax reading x sensitivity}}{R}$$

The figure 4.217×10^6 as given in equation (8) is constant only for the aforementioned conditions of volume, temperature, and pressure. Any variation in these values must be accompanied by a corresponding correction of the above constant. The factor K, which was previously calculated for normal uranium hexafluoride, may be determined for any specimen from data obtained by the Laboratory from samples taken from the cascade plant stream. The K factor for any given weight per cent uranium-235 is depicted in figure 11.

The calibration of the space recorder may be checked by the use of a one-milligram radium source as shown in figure 4. The source should be placed half-way up the vertical height of the signal can at specific distances from the outside wall. The minimum sensitivities given in the table correspond to the readings which should be obtained when the chamber is filled with 100% nitrogen at a pressure of 10 psia and at a temperature of 135°F.

SPACE RECORDER CALBRATION USING RADIUM SOURCE

FIGURE 4



DISTANCE (X INCHES) FROM OUTSIDE WALL OF SIGNAL CAN		OUTPUT SIGNAL IN VOLTS ± 20%
1 MG RADIUM SOURCE	2 MG RADIUM SOURCE	
6		1.10
8		0.80
10		0.65
	10	1.3

TABLE 1

CONSTANTS FOR URANIUM ISOTOPES

Isotope	Half Life, Years	Decay Constant	Number of Molecules Ionized in Nitrogen By One Alpha Particle
U-234	2.52×10^{5}	8.72×10^{-14}	142,000
U-235	8.91×10^{8}	2.47×10^{-17}	132,000
U-236	2.46×10^{7}	8.94×10^{-16}	136,000
U-238	4.49×10^{9}	4.90×10^{-18}	125,000

RECOMMENDED OPERATING PROCEDURES

Pressure

The normal operating pressure for the space recorder is 10 psia. A higher pressure slightly decreases the background current due to alpha particles resulting from corrosion products. However, this will cut the flow slightly and thus lengthen the time response.

For signals above approximately 6×10^{-9} ampere, the effect of recombination is too great to permit accurate measurements. It is possible that the signal can be operated at a lower pressure for the high concentrations. However, at pressures under 5 psia, the range of the alpha particle becomes greater than the radius of the signal can grid cage, resulting in a rapid loss of sensitivity. If low pressures are used, correction for this fact may be made by the use of figure 5.

Temperature

The recommended operating temperature for the signal can is 140°F.

Grid Potential

For low concentrations of uranium hexafluoride, a grid voltage of 300 volts should be used. Recombination effects are negligible in this range and the background ionization current is slightly less than it is at 750 volts. However, an effective means of compensating for recombination is to increase the accelerating voltage on the grid from 300 volts to 750 volts. It is important that the potential of the grid structure be held constant since any variation would induce charges on the collector wire, thus causing instability of the amplifier output.

Exposure of Signal Can to Uranium Hexafluoride

Since the rate of increase of ionization current background in a signal can depends upon the exposure to which the can has been subjected, it is desirable to hold the exposure to a minimum if the can is to be used for detecting the presence of low concentrations of uranium hexafluoride. This may be achieved in the K-312 section by dividing the range of analyses between two signal cans. The time of running at any concentration should vary inversely with the concentration.

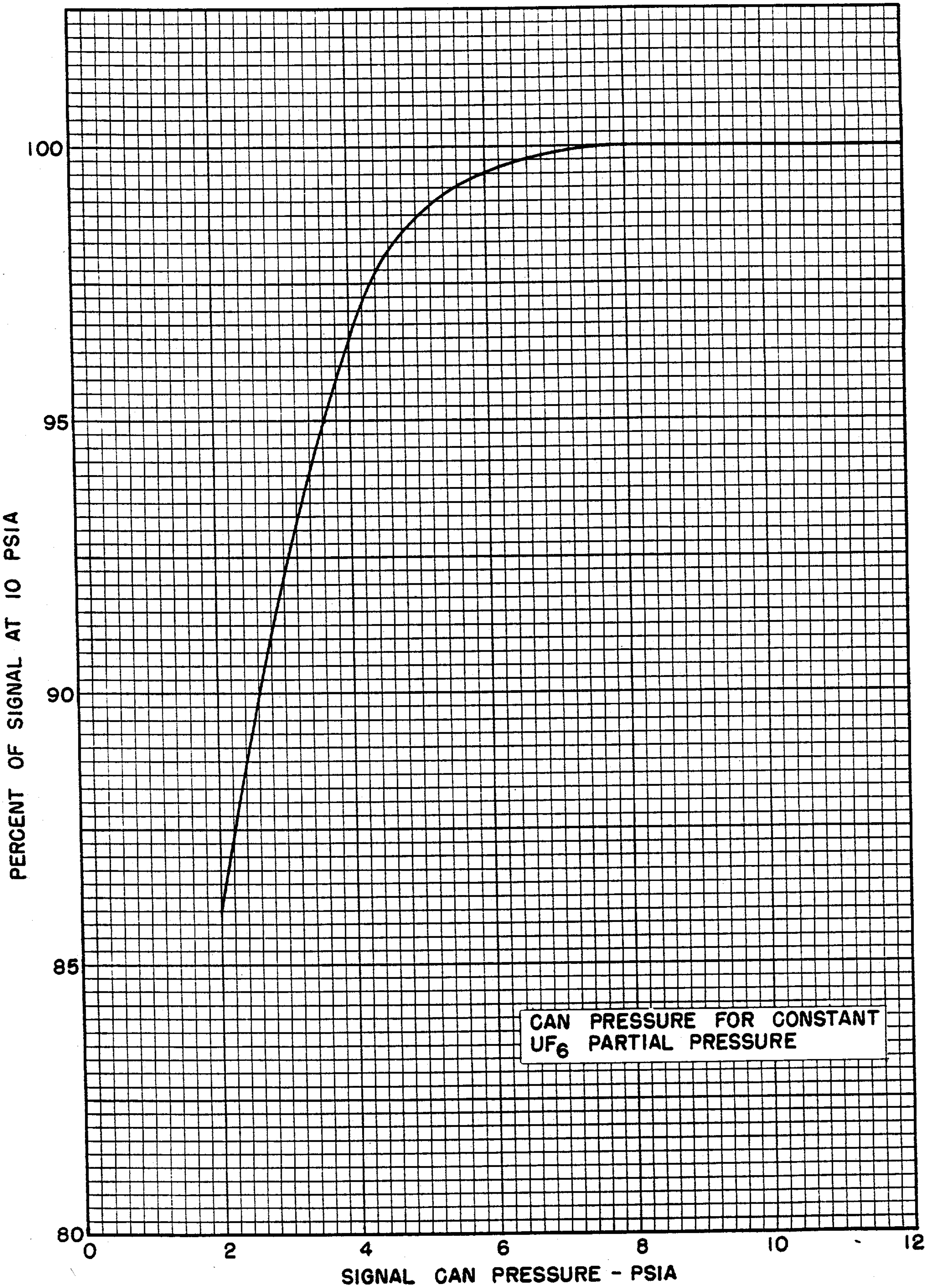
Permissible Background

For space recorders used to analyze low concentrations in the K-312 units and in the side purge units (normally "B" instrument), the background should not exceed 150 millivolts (signal of 75 x 1 on the micromax). Signal cans having backgrounds in excess of this value should be used only in those space recorders used to analyze high concentrations - as in the K-312 units (normally "A" instrument).

When the background of the signal can used in the "A" instrument exceeds 500 millivolts, it should be removed and decontaminated.

RELATIVE SIGNAL VS TOTAL SIGNAL

FIGURE 5



The ideal procedure is to replace a "B" can when necessary with a decontaminated unit. The unit which was removed may then be used as an "A" instrument since its background, though too high for use with low concentrations, is entirely satisfactory for use with the "A" instrument. This arrangement is not always practicable - in which case any replacement is made with a decontaminated unit.

See "Space Recorder Operation" for the reduction of the background signal by treatment with chlorine trifluoride.

Accuracy

The accuracy of the results obtained from the use of the space recorder will be seriously affected by the accuracy or knowledge of the following factors:

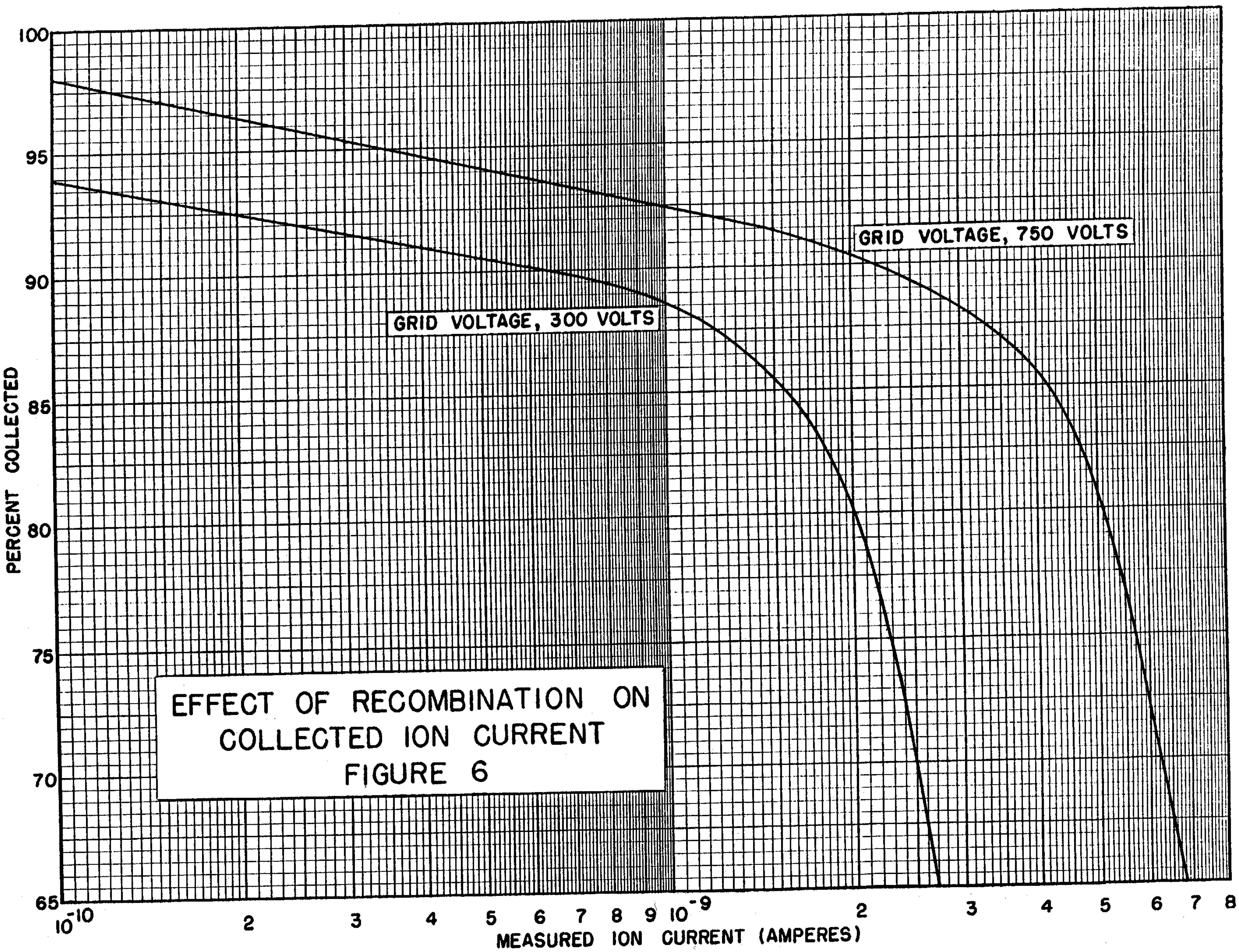
1. The background signal; this was previously discussed in the "Theory" section.

2. The uranium hexafluoride isotope enrichment figures as obtained from the laboratory.

3. Amount of recombination. Error due to this cause may be greatly reduced by the use of figure 6.

4. Pressure and temperature of gas. With normal precautions, the error due to the inexact measurements of these factors is slight.

5. Value of the preamplifier resistor. This may be checked by using a calibrated radium source.



EFFECT OF RECOMBINATION ON COLLECTED ION CURRENT

FIGURE 6

OPERATION OF THE SPACE RECORDER

Manifold Connections to Line Recorders and Space Recorders in the K-312 Section

Normally, the line recorders are employed for analyzing gas containing one or more per cent of uranium hexafluoride, and the space recorder is used for low concentrations. It may be seen from figure 7 that it is possible to operate two line recorders simultaneously on the lower part of the purge cascade and two space recorders on the upper part. If this is done, it is important that the transfer line connecting valves Nos. 21, 28, and 35 be kept filled with gaseous nitrogen. Otherwise, leakage of uranium hexafluoride from the high concentrations in headers X and Y could occur through valves 35 and 42 into the space recorder. If the space recorder connected to valve 42 were analyzing gas with very low concentrations of uranium hexafluoride, any leak in the valve seats could thus seriously contaminate the gas flowing to the space recorder. Gas should be returned to the cascade at the point having most nearly the same uranium hexafluoride concentration.

Background Check

The recommended procedure for taking a background check on the space recorder in the K-312 section is as follows:

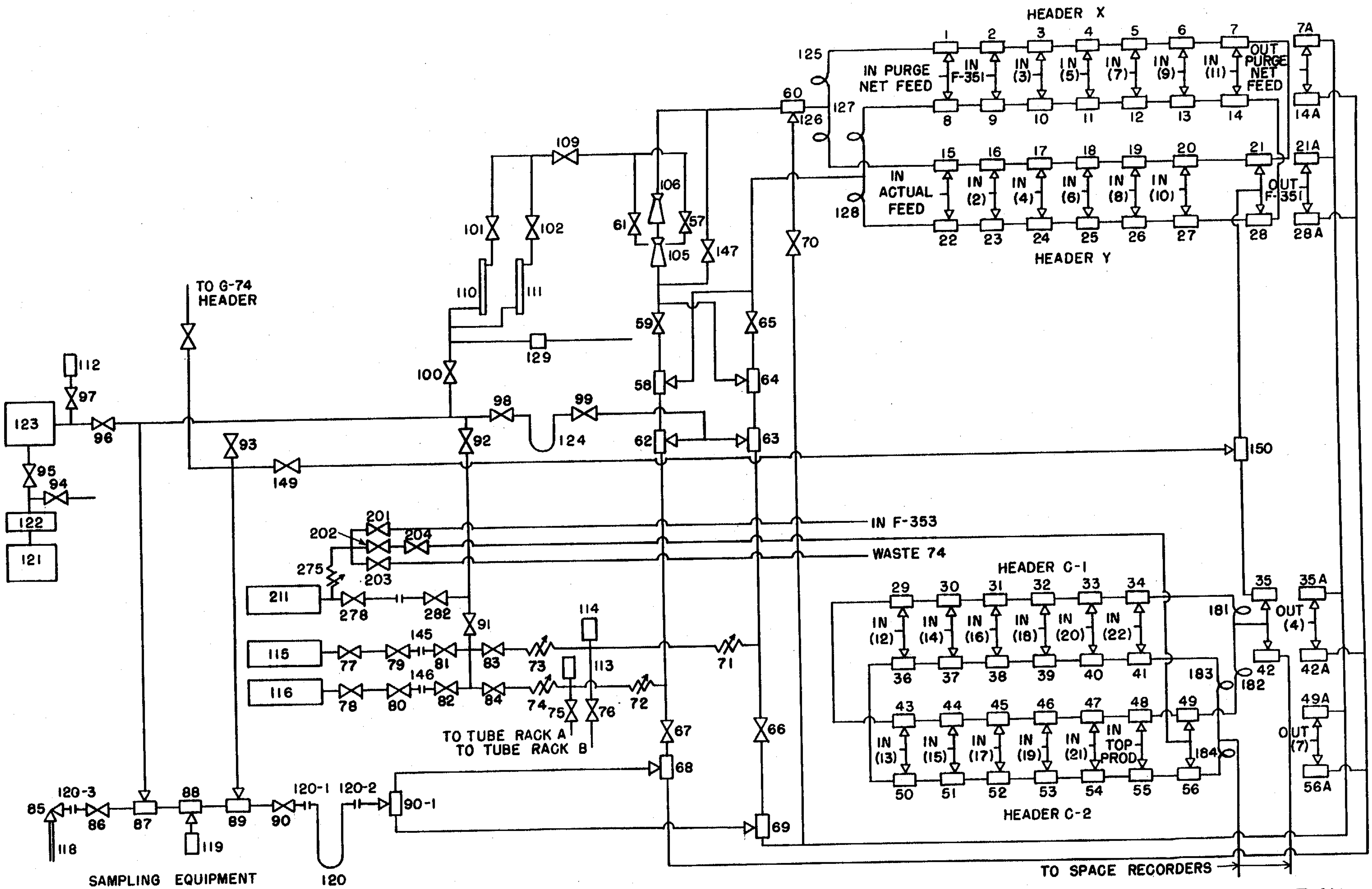
1. Open the nitrogen header valve and valve No. 48.
2. Close space recorder inlet valve No. 17.
3. Crack valve No. 13 to maintain 2 psia suction in the B-4 pumps (should have reading of 50 divisions on P.I. 7).
4. The background is indicated when the micromax reading is steady or has leveled off.

Signal Can Replacement

When the maximum allowable background has been reached, the signal can must be replaced by one with a low residual background. Whenever possible, excessively contaminated signal cans removed from "A" manifolds should be replaced with signal cans rejected for use in the "B" manifolds. Signal cans removed from the "A" manifolds are then decontaminated and reconditioned and put back into a reserve stock from which signal cans are drawn for use in the "B" manifolds.

The following procedure may be used for replacing signal cans in the K-312 section:

1. Purge signal can and lines as explained for taking a background check.



NOTE: NUMBERS IN PARENTHESES IDENTIFY CELLS

FLOW DIAGRAM FOR PURGE CASCADE MANIFOLD - K-312 SECTION

FIGURE 7

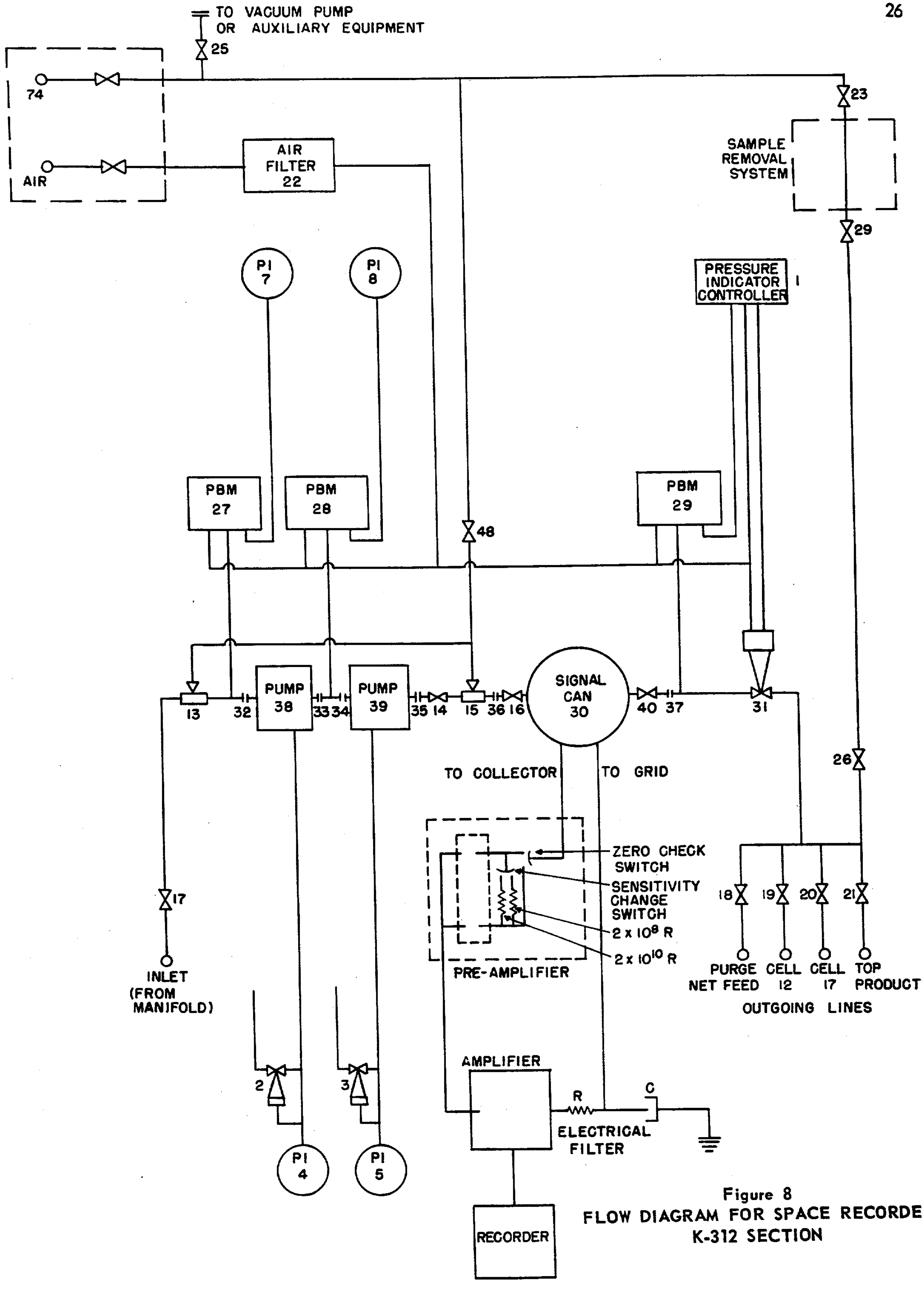


Figure 8
FLOW DIAGRAM FOR SPACE RECORDER
K-312 SECTION

2. The lines may be assumed to be purged when the micromax reads only background.

3. Shut off the B-4 pumps.

4. Close the nitrogen header valve, block valve No. 14, and outlet valve No. 20 (cell 12). Torque each to 35 ft.-lbs.

5. Close valves Nos. 16 and 40 (torque to 35 ft.-lbs.) and insure that valve No. 15 is closed and torqued. Turn set-point up to 15 psia on P.I.C.

6. Remove bolts from signal can flanges Nos. 36 and 37.

7. Shut off power to the panel rack at breaker panel and allow several minutes for the grid capacitor to discharge.

8. Detach electrical cables from signal can and preamplifier. Signal can is now ready for removal.

9. Remove the signal can from the manifold, utilizing the line recorder tube rack lift and special signal can lift adapter.

10. Prior to installing the new signal can in the manifold, remove the preamplifier from the contaminated can and position it on the new one. Care should be taken with the electrical connection to the collector wire during this operation.

11. Place new signal can in manifold and leak-test it.

12. Connect grid cable to the signal can and the amplifier, and the switching cables to the preamplifier.

13. Bolt flanges after installing new aluminum gaskets.

14. Open valves Nos. 16 and 40.

15. The space recorder may now be placed on stream.

Reduction of the Signal Can Background by Chlorine Trifluoride Treatment

When the background signal of a contaminated signal can becomes excessively large for the concentrations of uranium hexafluoride being measured, the system may be readily restored to high sensitivity by the replacement of the signal can. However, due to the expense of this operation, in-place decontamination with the use of chlorine trifluoride has satisfactorily been practiced with the units in the K-312 section. After treatment with several successive charges of chlorine trifluoride (up to twelve), the background was reduced to an acceptable figure. It has been a matter of conjecture as to the effect of chlorine trifluoride upon the sensitive grid and collector wires within the signal can. However, to date, no adverse effect has been observed as a result of the chlorine trifluoride treatment. More extensive use of this practice should follow only after the consideration of the relative expense of signal can replacement with that of the possible replacement of the signal can grid. This consideration would become unnecessary should it be shown that the treatment with chlorine trifluoride is harmless to the grid structure as compared with other decontamination procedures.

Placement of Space Recorder On Stream

It may be assumed that a contaminated signal can has been replaced with a new one as previously described. The instrument will be started by taking a background reading. This procedure involves two major steps: the electronic units must be functioning, and the proper sequence involving the manifold must be observed.

A. Panel Rack Adjustment

1. Main Control Panel: The "line" switch connects the power supply to the panel rack; the "control" switch connects the power to the electronic equipment; and the manifold switch connects the power from the panel rack to the manifold equipment. All three switches should be in the "ON" position for operation.

2. Power Supply and Switching Panel: The power supply "timer" switch should be on the "ON" position; the "zero" switch should be on "MANUAL"; and the resistor selector should be on the "high" resistor. With this arrangement, the red light for the zero check and the white light for the high resistor should be lit and the exposed V.R. tube in the high voltage supply should display a light-blue glow.

3. D.C. Amplifier: The power should be turned on and the filament, regulation, and battery output noted to insure that they are within the operating range. The filament and regulation should fall within the red segment and may be adjusted to the central black line by means of adjusting screws in the rear of the panel. The batteries are satisfactory if their output falls within or beyond the red segment when the battery button is depressed. The output meter is balanced at zero on the X-1 sensitivity by manipulating the coarse, medium, and fine rheostats. The D.C. amplifier and preamplifier will drift for several hours and should reach equilibrium within 72 hours; however, the drift should be small enough to make readings practicable in approximately twenty minutes. The final adjustment to zero may then be made, after which the output meter selector switch is turned to the "OFF" position.

   When operating the D.C. amplifier only, switch the recorder sensitivity to the "OFF" position. When operating both the recorder and D.C. amplifier, adjust both units to corresponding sensitivities. The D.C. amplifier sensitivity switch will be set at a multiplier ten times that of the recorder sensitivity for corresponding readings--the amplifier indicating 20 mv full scale in the X-1 position compared to 200 mv full scale for the recorder in the X-1 position.

4. Micromax: The signal can output is recorded by the micromax. When the zero switch is on "MANUAL" and with X-1 sensitivity, the micromax should read zero. The driving mechanism is controlled by the micromax switch on top of the instrument. Return the "Zero" switch to "automatic." The red light will go out immediately; a few seconds later it will flash momentarily which indicates that the instrument is in condition to record the signal (background).

B. Manifold Adjustment

Turn the amplifier sensitivity switch to the "OFF" position until the following procedure is completed:

1. Evacuate the manifold and signal can to cell No. 12 through valve No. 20 (valves Nos. 13, 14, 15, 16, 48, 40, 31, 23, and 29 open; valves Nos. 17, 18, 19, 21, and 25 closed).

2. When pressure on the P.I.C. reaches cell pressure, close valve No. 20.

3. Close valves Nos. 2 and 3 (counterclockwise rotation) and start the B-4 pumps.

4. P.I.'s Nos. 4 and 5 should indicate a falling pressure and attain a vacuum of 25 inches of mercury. The failure to do this indicates faulty bellows evacuation.

5. Close valves Nos. 26 and 48.

6. Open the nitrogen header to pressure the sample removal system to 20 psia.

7. Close valves Nos. 23 and 29. (Note the pressure on the P.I.C. to detect seat leaks in valves Nos. 26 and 48.)

8. With the P.I.C. set-point on 10 psia, close valve No. 15 and open valve No. 20.

9. Slowly open valve No. 48 and adjust the flow so that the inlet pressure to the first B-4 pump (P.I. No. 7) does not exceed 2 psia.

10. Adjust B-4 pump bellows chamber pressure (P.I.'s 4 and 5) to the mean inlet and outlet pressures to the pumps (P.I.'s 7 and 8 to P.I.C.).

11. After the signal can pressure has reached 10 psia, turn the micromax selector switch (channel D) to the X-1 position, and permit the background to be recorded.

Space Recorder Operation in Cold Trap Facilities

A. Use

The purpose of the space recorder in cold trap operations is to indicate the concentration of uranium hexafluoride in the alumina trap lines. If this concentration becomes excessive, steps must be taken to eliminate or reduce the loss of uranium hexafluoride through the discharge stack.

B. Protection

The signal can becomes contaminated by overexposure to high concentrations of uranium hexafluoride. In the event that large quantities of process gas are released into the stack due to valve failure or operating error, the inlet to the space recorder must be closed at once and the signal can purged.

The backup of gases into the signal can is prevented by closing the space recorder valve into the pump suction header and the space recorder inlet valves prior to stopping the cold trap pumps.

C. Background Check

A background check should be run every week, when excessive contamination is suspected, or whenever a new signal can is installed. The check is run as follows:

1. Insure that the inlet valves from the stack are closed.

2. Open valve to Beach-Russ pump suction.

3. Open capillary by-pass.

4. When the signal can has attained the Beach-Russ pump suction pressure, crack the purge valve and allow nitrogen to flow through the signal can for one-half hour with 5-10 psia pressure in the can.

5. Close the capillary by-pass and set the purge valve to maintain 10 psia in the signal can. This is 66.7 divisions on the 0-15 P.I.'s located on the signal can rack above the micromax (or 50 divisions on a 0-20 P.I.).

6. Turn power switches on switching and D.C. amplifier panels to "ON" position.

7. Test the batteries and the filament.

8. Set the sensitivity switch to "OFF" position.

9. Set D channel sensitivity switch to "OFF" position.

10. Place the zero switch on "MANUAL" and the output sensitivity on X-1. Set the output at zero, using the coarse, medium, and fine adjustment knobs.

11. When the amplifier drift ceases and a constant zero is maintained, switch the zero switch to "AUTOMATIC" and turn the sensitivity knob (the D channel when the JS-307G amplifier is used) to the proper sensitivity for recording the signal.

12. When the signal becomes constant, the chart reading may be recorded.

Placing the Space Recorder On-Stream

For panel rack adjustment, see "Placement of Space Recorder On-Stream" for the K-312 section.

1. Turn on power to the switching and D.C. amplifier panels.

2. Check the filament and batteries.

3. Set the amplifier on automatic zero.

4. Set the sensitivity switch to the high position.

5. Open the valve to the Beach-Russ suction.

6. Open the capillary by-pass.

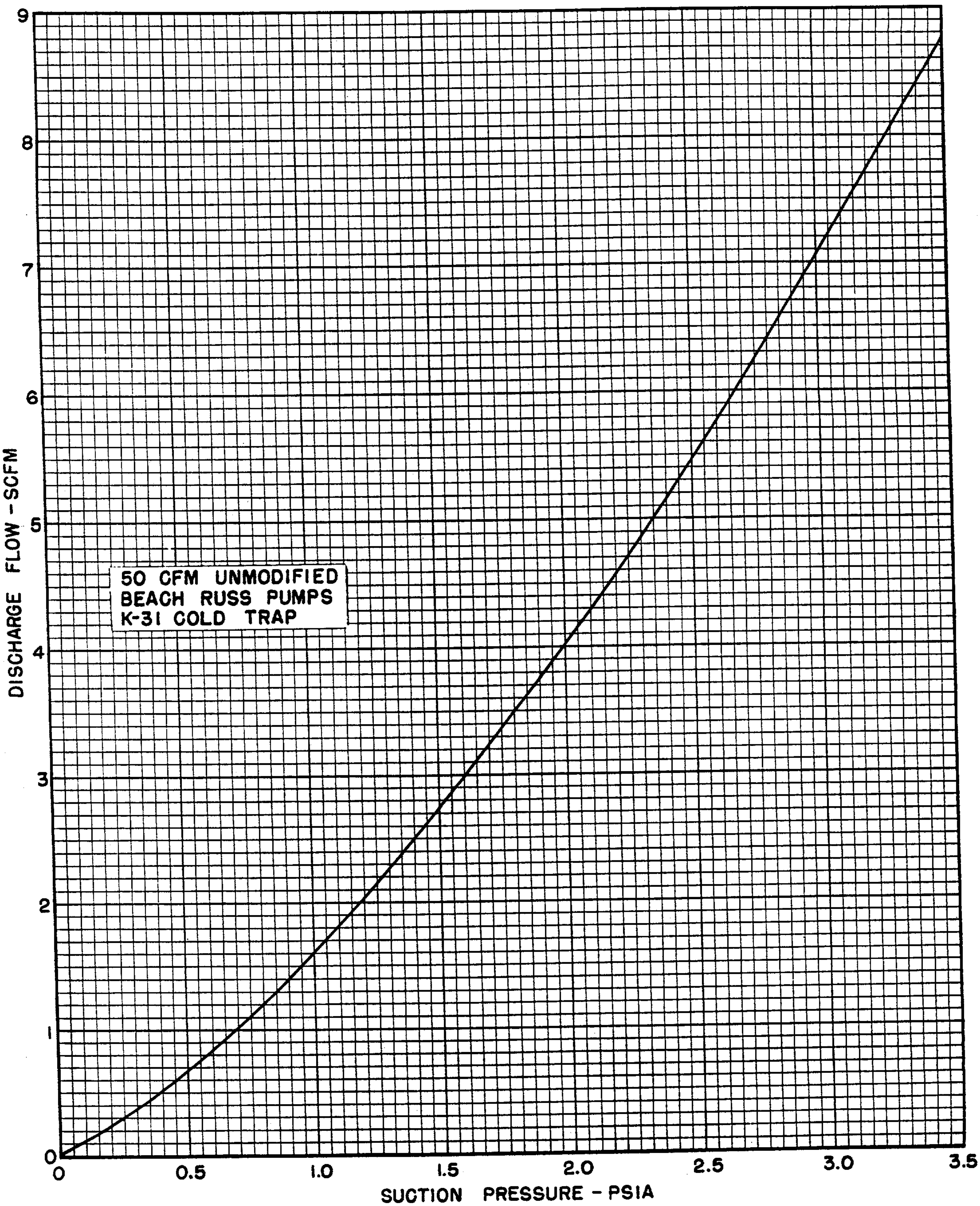
7. When the signal can pressure attains the Beach-Russ suction pressure, close the by-pass and open the inlet valve from the stack.

8. Adjust the Mohr valve to maintain 10 psia in the signal can.

9. Set the "D" channel sensitivity switch on the proper sensitivity to record the signal.

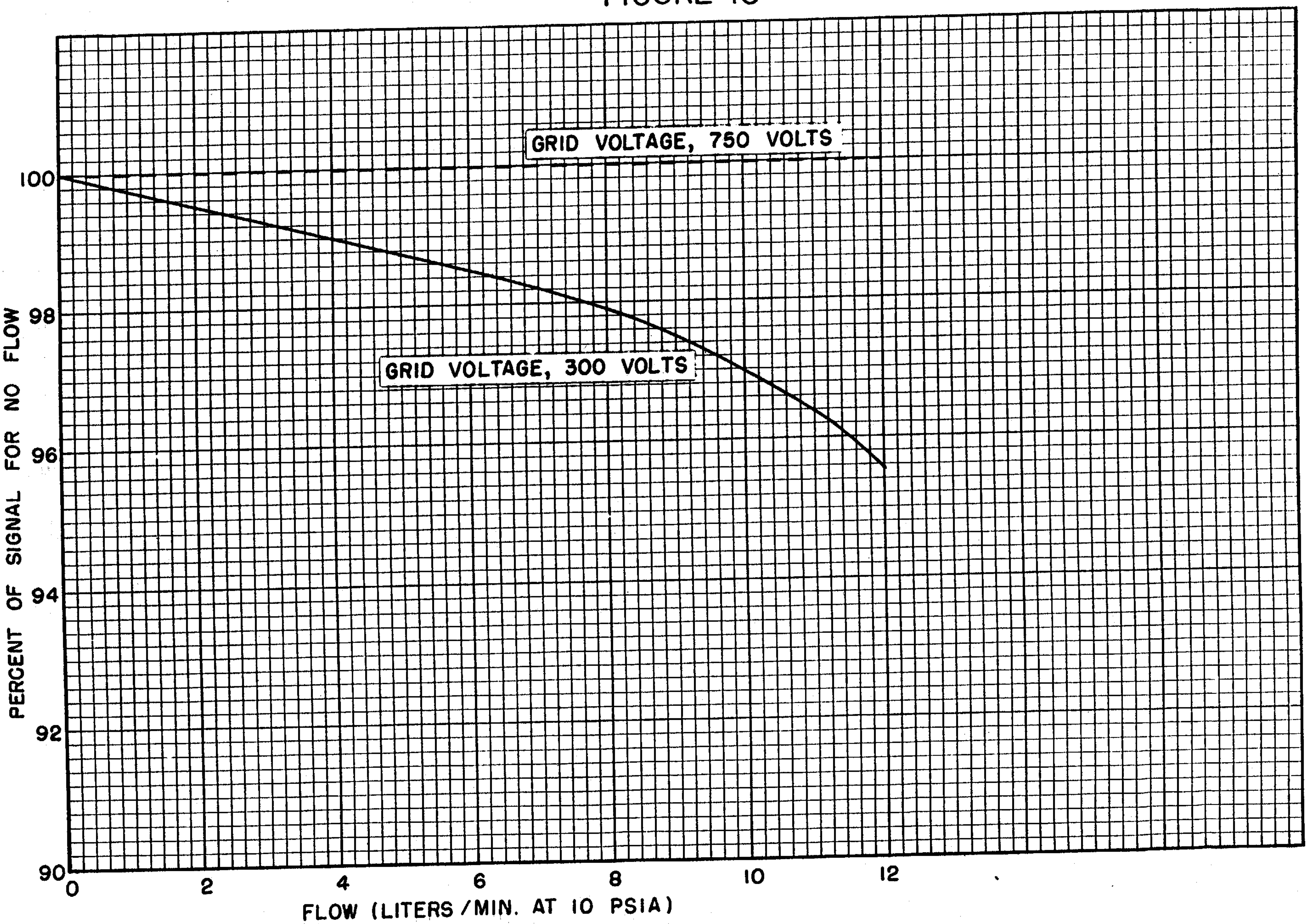
DISCHARGE FLOW VS SUCTION PRESSURE

FIGURE 9



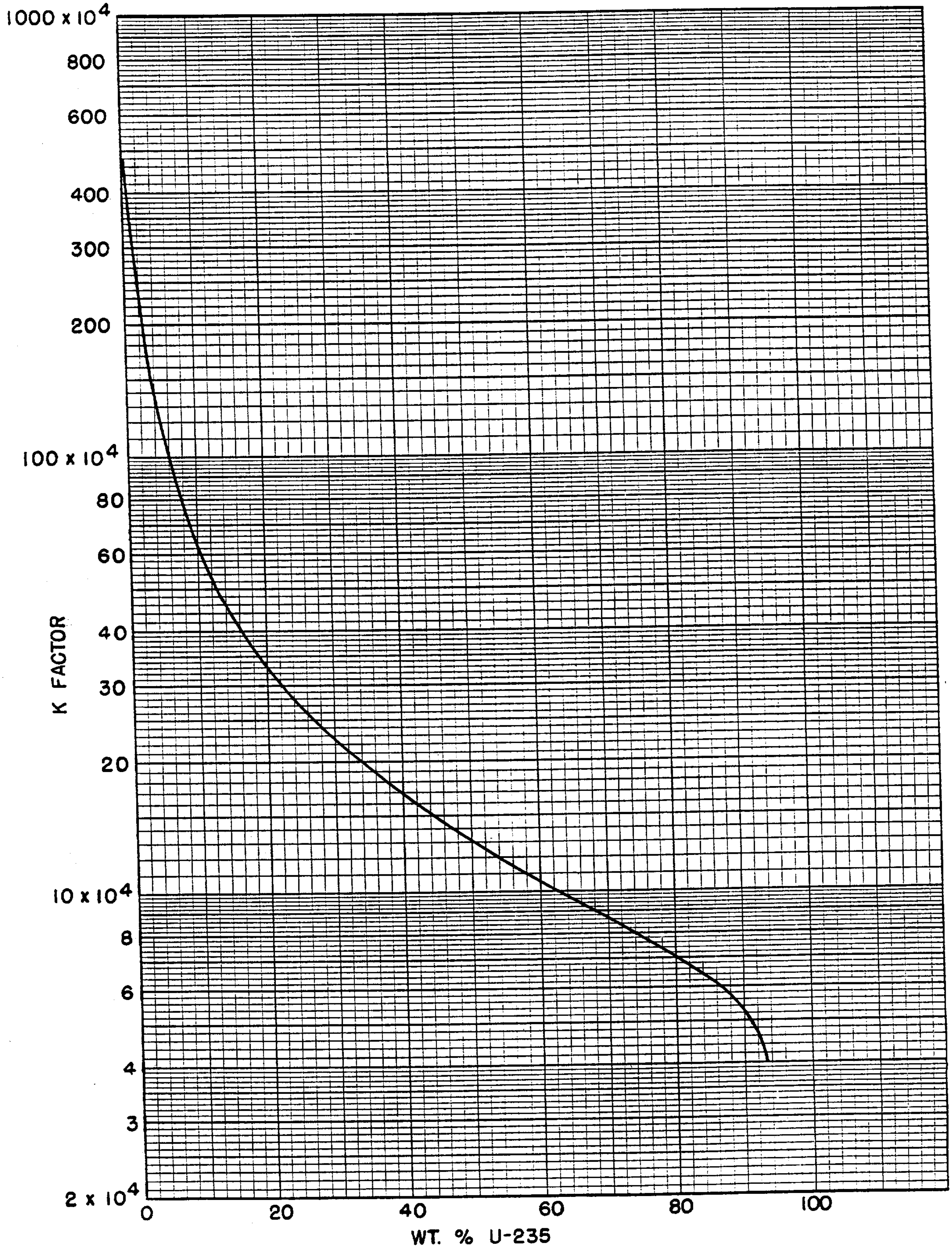
RELATIVE SIGNAL VS FLOW

FIGURE 10



K FACTOR VS. WEIGHT PERCENT U-235

FIGURE 11



APPENDIX I

Process gas losses to the roof in cold trap operations may be calculated by the following procedure:

Figure 9 shows the standard cubic feet per minute (SCFM) pumped by a Beach-Russ pump at various pump suction pressures.

Pounds uranium hexafluoride lost to roof per day = SCF/min./pump x number of pumps x $\frac{\text{mole }\%}{100}$ x $\frac{1440\text{ min.}}{\text{day}}$

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